EFFECTS OF STORAGE ON STARCH AND SUGARS CONTENTS OF MAINE POTATOES

R. H. Treadway, Margaret D. Walsh and Madelyn F. Osborne

*Eastern Regional Research Laboratory**
Philadelphia 18, Pa.

Large surpluses of potatoes in 1943 and 1946 have spurred efforts to expand non-food outlets, such as starch manufacture. In the manufacture of potato starch and in other potato processing, it is necessary to store potatoes for several months in order to extend the operating season. Although many investigations have been carried out on potato storage, most of this work has dealt with the determination of proper storage conditions for table stock and seed potatoes. There is a real need for information on the storage of potatoes to be used in industrial processes. Operators of starch factories, for example, have noted that potatoes yield less starch in late winter and spring after storage at a relatively low temperature. Although no supporting data are available, they believe that starch produced late in the operating season is of lower quality than

*One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

that obtained from freshly dug potatoes. Published reports show that storage at low temperatures decreases the percentage of starch and increases the percentage of sugars in potatoes, but it was considered desirable to obtain similar data on the types of potatoes commonly used in starch manufacture and to compare the quality of commercial starch produced from potatoes early in the season with that of starch from stored potatoes.

The two most popular varieties of potato grown in Maine—the Katahdin and the Green Mountain—were selected for the storage experiments, since most of the potatoes processed into starch in Maine are of these varieties. The potatoes were stored at temperatures ranging from 34° to 60° F. According to Stuart *et al.* (11), the temperature of a potato storage house in Aroostook County, Maine, ranges from 34° to 45° F. during the winter. Heat is supplied during extremely cold weather to prevent freezing, and increased ventilation with outside air is employed during mild weather to offset heat of respiration.

Review of the Literature

The most important chemical changes occurring during the storage of potatoes are in the starch and sugars. Müller-Thurgau (7) reported in 1882 that the sugar content of potatoes increased during cold storage or on slow freezing. This investigator also observed that when potatoes were taken from cold storage and exposed to a higher temperature (68° F.) the sugar content decreased. According to Appleman (1), three processes occur in a potato: (a) respiration, which consumes sugar by converting it into carbon dioxide and water; (b) conversion of starch to sugar by amylolytic enzymes; and (c) conversion of sugar to starch ,presumably by starch-synthesizing enzymes). At low temperatures sugars increase and starch decreases; at higher temperatures, sugars decrease as a result of respiration and starch synthesis. Potatoes lose weight in storage, owing partly to evaporation of water and partly to respiration. Many investigators, including Hopkins (5), Barker (3), Kimbrough (6), and Smith (9), have studied the factors influencing rate of respiration.

Research workers in the Bureau of Plant Industry, Soils, and Agricultural Engineering have contributed to the potato-storage literature during the past 15 years. In a study on the influence of storage conditions on respiratory and other physiological changes, carbohydrate composition, and culinary quality of potatoes, Wright, Peacock, Whiteman and Whiteman (13) found that the percentage of starch decreased with decrease in storage temperature and that the sugar content increased in a commensurate amount. Wright (14) measured the decrease in content

of sugars accumulated during 5 months' storage at 32° F., after transferral of the potatoes to 60° storage. Wright, Caldwell, Whiteman and Culpepper (12), who recently investigated the effect of storage conditions on the quality of dehydrated potatoes, concluded that accumulation of sugars during low-temperature storage results in a sweet, soggy and badly discolored potato.

Denny and Thornton (4) have pointed out that the amount of sugars formed during cold storage of potatoes depends on variety as well as temperature. They likewise found that the extent of de-sugaring which occurs on exposure to higher temperatures is different in different varieties.

Barham, Kramer, and Reed (2) studied the changes in weight and in starch content of potatoes during 6 months (July to January) of cold and shed storage in Kansas. In this period the starch content fell from 14.7 to 9.6 per cent in cold storage and to 10.3 per cent in shed storage.

Materials and Methods

U. S. No. 1 Katahdin and Green Mountain potatoes of the 1945 crop were used in this study. The potatoes were grown at the Aroostook Farm of the Maine Agricultural Experiment Station, Presque Isle, on Caribou loam, fertilized with one-half ton per acre of fertilizer ($2N—4P_2O_5—5K_2O$) containing 1 per cent magnesium. The vines were sprayed with Bordeaux mixture (5 Ca $(OH)_2$-5 Cu $(SO_4)_2$-50 water) six times during the season. The vines were also sprayed with calcium arsenate solution, 2 pounds per 100 gallons of water. Except for a slight amount of leaf roll, disease in the potatoes was non-existent. Temperature and moisture were normal up to the 1st of August at Aroostook Farm, but a dry August produced smaller potatoes than usual. The potatoes were harvested on the 27th of September and held for 5 days at 50° to 60° F. after harvesting.

The storage boxes held 55-60 pounds of potatoes and were ventilated through slots about ¾ inch wide, placed at the bottom of one side and top of the opposite side. Care was taken in mixing and in distributing the potatoes in order to obtain uniform samples.

On the 2nd of October the potatoes were weighed, sampled, and then placed in storage bins at Aroostook Farm at the following temperatures and relative humidities: 34° F. and 81 per cent R. H.; 36° F. and 83 per cent R. H.; 38° F. and 82 per cent R. H.; 42° F. and 82 per cent R. H.; 50° F. and 87 per cent R. H.; 60° F. and 68 per cent R. H. Duplicate boxes of each variety were placed in each storage bin, one to serve as a source of samples and the other as a weight control. After 7,

13, 22, 29 and 37 weeks the potatoes were examined, weighed, and sampled. Each time duplicate three-pound samples (about 10 potatoes) were removed from each box for analytical determinations. One sample was finely ground (with a high-speed rasp or hammer mill), moisture was determined, and a portion was immediately preserved in alcohol for later analysis at the Eastern Regional Research Laboratory, where all other determinations were made. Sufficient absolute alcohol was used to give a final concentration of approximately 80 per cent alcohol after dilution with the potato juice. The alcohol-insoluble solids were used for the starch determination. It was necessary to determine sugars only in the alcoholic extract. When approximately 90 grams of finely ground potato were allowed to stand in 360 cubic centimeters of absolute alcohol for 1 week or longer at room temperature before analysis, practically all the sugars leached out into the 80 per cent alcohol. The duplicate set of samples was kept for about 2 weeks at ordinary temperatures (60°—70° F.) , then ground and immediately analyzed.

Moisture was determined by drying a 15 to 20-gram sample of ground potato, spread thinly over the bottom of a shallow dish, in an oven at 120-°-135° F. for 4 to 6 hours and then at 275° F. for 2 hours. Starch was determined polarimetrically by the Steiner and Guthrie method (10). Sugars were determined by the official gravinometric methods (8) of the Association of Official Agricultural Chemists.

Data and Results

Table 1 shows the changes in starch content during storage at the various temperatures and after 2 weeks at room temperature following removal from cold storage. The loss of starch was considerable at the lower temperatures 34°, 36°, and 38° F. At higher temperatures the change was less. The Katahdin potatoes changed little in starch content after 7 weeks' storage. The Green Mountains, however, continued to lose starch up to the thirteenth week of storage. After the potatoes were withdrawn from cold storage and kept at room temperature for 2 weeks or longer, the values for starch increased, approaching, on a percentage basis, the original value. The Green Mountain variety showed this tendency more definitely than the Katahdin variety.

It will be noted that some of the starch values for the Green Mountains, on the wet basis, are higher than the original starch content, undoubtedly owing to unusual loss of moisture. On the dry basis, however, no values exceed the original beyond the expected experimental error.

The changes in sugar content are given in table 2. A large increase in total sugars (primarily in reducing sugar) was found in potatoes stored at 34° and 36° F. The greatest change took place during the first 13 weeks

TABLE I.—*Changes in starch content of potatoes during storage at various temperatures*[a]

Storage Temperature, °F.	Starch Content after Storage of (Weeks)—					Starch Content after 2 Weeks at Room Temperature Following Withdrawal from Storage of (Weeks)—				
	7 Per cent	13 Per cent	22 Per cent	29 Per cent	37 Per cent	7 Per cent	13 Per cent	22 Per cent	29 Per cent	37 Per cent
	Katahdin (Original Starch Content 13.5 per cent (72.3).)									
34	9.7 (56.1)	10.3 (54.5)	9.6 (55.9)	9.8 (55.2)	9.9 (56.2)	12.1 (64.2)	12.4 (63.2)	13.1 (66.5)	10.4 (57.9)	10.8 (60.3)
36	10.9 (60.9)	9.6 (56.9)	10.2 (59.6)	10.1 (58.2)	9.7 (56.9)	12.7 (65.8)	12.8 (64.2)	12.5 (65.3)	10.6 (56.1)	12.2 (64.3)
38	11.5 (62.8)	11.3 (63.6)	11.1 (64.4)	—	11.2 (61.1)	12.9 (68.9)	13.4 (66.0)	13.0 (66.4)	12.0 (62.9)	11.4 (63.3)
42	11.9 (65.7)	12.1 (67.3)	11.5 (67.5)	—	12.0 (66.1)	13.6 (71.5)	13.1 (67.7)	12.6 (66.2)	12.5 (61.4)	13.6 (66.5)
50	11.9 (66.1)	12.6 (68.9)	12.1 (68.9)	12.1 (71.7)	--b/	13.0 (69.7)	13.4 (66.9)	13.4 (68.1)	11.4 (58.6)	--b/
60	12.8 (71.1)	13.2 (73.6)	12.0 (68.4)	12.1 (62.9)	--b/	13.3 (69.9)	13.3 (64.0)	13.8 (65.6)	13.8 (56.9)	--b/
	Green Mountain (Original Starch Content: 15.6 per cent (73.3).)									
34	13.0 (69.0)	11.4 (58.8)	12.5 (62.7)	11.8 (60.0)	12.1 (61.5)	15.2 (71.3)	15.1 (71.7)	14.9 (70.1)	14.6 (70.1)	15.6 (71.1)
36	14.1 (70.8)	12.4 (63.5)	12.3 (62.9)	13.4 (66.9)	11.7 (61.1)	15.5 (71.5)	13.6 (66.8)	16.5 (73.4)	15.3 (72.1)	15.3 (70.2)
38	15.0 (73.9)	13.9 (69.3)	13.1 (67.0)	13.6 (70.2)	13.8 (67.1)	15.9 (74.1)	15.7 (72.7)	16.2 (72.3)	14.6 (68.1)	16.8 (71.1)
42	16.8 (78.9)	14.1 (71.6)	12.7 (68.1)	14.4 (70.8)	15.7 (72.7)	15.9 (73.3)	16.5 (73.6)	16.1 (73.6)	15.8 (71.9)	17.1 (71.4)
50	16.6 (81.8)	14.6 (72.1)	15.2 (70.8)	14.7 (73.1)	--b/	15.7 (73.5)	16.2 (73.9)	16.4 (73.4)	17.6 (74.0)	--b/
60	16.6 (80.2)	15.4 (73.4)	14.8 (70.5)	14.7 (66.0)	--b/	16.0 (73.4)	16.2 (73.5)	17.5 (73.4)	17.1 (60.0)	--b/

a. Figures in parenthesis are on dry basis.
b. No determinations made. Sprouted too extensively to be utilized for any purpose.

TABLE 2.—*Changes in sugars Content of potatoes during storage at various temperatures*[a]

Storage Temperature, °F.	Total Sugars, Content after Storage for (Weeks)—					Reducing Sugars, Content after Storage for (Weeks)—				
	7 Per cent	13 Per cent	22 Per cent	29 Per cent	37 Per cent	7 Per cent	13 Per cent	22 Per cent	29 Per cent	37 Per cent
	Katahdins (Original Content: Total Sugars, 0.33 per cent (1.76); Reducing Sugars, 0.1 per cent (0.56).)									
34	1.8 (8.5)	3.2 (17.1)	2.5 (14.8)	2.4 (13.5)	3.1 (17.5)	1.4 (8.0)	1.9 (10.0)	1.8 (10.9)	1.5 (8.1)	1.9 (10.5)
36	1.2 (7.0)	2.6 (15.3)	2.6 (15.3)	2.1 (13.4)	2.1 (12.2)	1.4 (7.9)	1.8 (10.3)	1.9 (10.9)	1.6 (8.9)	1.5 (8.7)
38	0.8 (4.5)	1.5 (9.0)	1.2 (6.8)	—	1.0 (5.3)	0.8 (4.6)	1.1 (6.4)	0.9 (5.5)	—	0.8 (4.4)
42	0.4 (2.1)	0.5 (2.6)	0.6 (3.6)	—	0.3 (1.8)	0.3 (1.7)	0.1 (0.5)	0.3 (1.7)	—	0.3 (1.5)
50	0.2 (0.9)	0.25 (1.2)	0.3 (1.7)	0.3 (1.9)	—b/	0.1 (0.6)	— c/	0.1 (0.7)	0.2 (0.9)	— b/
60	0.2 (1.0)	0.2 (1.1)	0.3 (1.7)	0.6 (2.9)	—b/	0.1 (0.6)	— c/	0.1 (0.8)	0.4 (1.9)	— b/
	Green Mountain (Original Content: Total Sugars, 0.60 per cent (2.9); Reducing Sugars, 0.24 per cent (1.1).)									
34	2.9 (14.4)	3.3 (16.7)	2.6 (13.0)	2.5 (12.7)	2.3 (11.9)	1.7 (8.4)	2.1 (10.8)	1.6. (8.1)	1.8 (9.0)	1.8 (9.1)
36	2.1 (10.8)	2.7 (13.7)	2.0 (10.5)	1.8 (8.8)	2.3 (12.2)	1.5 (7.5)	1.9 (9.5)	1.5 (7.6)	1.3 (6.6)	2.0 (10.5)
38	1.6 (8.0)	1.8 (9.2)	1.0 (4.9)	1.2 (6.4)	1.3 (6.4)	1.1 (5.3)	1.3 (6.6)	1.2 (6.0)	1.0 (5.0)	1.1 (5.3)
42	0.6 (2.8)	0.9 (4.3)	0.7 (3.7)	0.7 (3.6)	0.6 (2.7)	0.4 (2.0)	0.4 (2.0)	0.6 (3.2)	0.5 (2.6)	0.5 (2.3)
50	0.6 (2.9)	0.7 (3.3)	0.4 (1.6)	0.6 (2.8)	— b/	0.35 (1.7)	0.2 (0.9)	0.3 (1.1)	0.6 (3.1)	— b/
60	0.4 (2.0)	0.5 (2.5)	0.4 (1.8)	1.3 (5.9)	— b/	0.3 (1.4)	0.1 (0.5)	0.3 (1.3)	0.7 (2.9)	— b/

a. Figures in parenthesis are on dry basis.
b. No determinations made. Sprouted too extensively to be utilized for any purpose.
c. Only trace present.

of storage. During the next 24 weeks the changes were less significant. At storage temperatures of 38° and 42° F., the increase in both total and reducing sugars was slight, and at 50° and 60° F. there was even a slight reduction in the amount of total sugars, particularly in the Kathadin variety.

As a general rule, the values for both reducing and total sugars of potatoes from cold storage decreased decidedly after 2 weeks' exposure to ordinary temperatures. Katahdins stored at 34° F. and sampled after 7, 13, and 22 weeks, for example, contained 8-½ to 17 per cent total sugars, as shown in table 2. (Data on the dry basis are discussed here to facili-

TABLE 3.—*Total sugars content of potatoes kept at room temperature for about 2 weeks after removal from cold storage*[a, b].

(Same samples as in table 2)

Storage Temperature, °F.	Katahdin			Green Mountain		
	Total Sugars Content after Storage for (Weeks)			Total Sugars Content after Storage for (Weeks)		
	7 Per cent	13 Per cent	22 Per cent	7 Per cent	13 Per cent	22 Per cent
34	1.1 (5.9)	1.0 (5.1)	1.0 (4.8)	0.6 (3.9)	0.8 (3.6)	0.7 (3.2)
36	0.9 (4.5)	0.8 (4.2)	0.8 (4.0)	0.5 (2.4)	0.7 (3.7)	0.7 (2.9)
38	0.6 (3.4)	0.7 (3.3)	0.7 (3.8)	0.5 (2.2)	0.6 (3.0)	0.7 (3.0)

a. Original sugar contents the same as in sugar table 2.
b. Figures in parenthesis are on dry basis.

tate comparisons). Table 3 shows that the total sugars content was reduced to 5-6 per cent after these potatoes were removed to room temperature. Likewise the total sugars contents of the Katahdins stored at 36° and 38° decreased to 7-15 and 4½—9 per cent, respectively to about 3-4 per cent. At 42°, the moderately low sugar contents remained about the same during the after-storage period. At 50° and 60°, the sugar contents actually increased. For example, Katahdins kept at 60° for 29 weeks contained 5.9 per cent total sugars, which increased to 7.8 per cent in the following 2 weeks. The potatoes which increased in sugar content sprouted considerably during this period; increase in sugar is believed to be associated with extensive sprouting, as pointed out in the discussion of table 5.

On removal from cold storage, the Green Mountain potatoes behaved about the same as the Katahdins. Table 3 shows that the Green Mountain variety, although it originally developed more total sugars than did the Katahdins, reached even slightly lower sugar values during reconditioning. Like the Katahdin variety, the Green Mountain potatoes lost only a small amount of their relatively low sugar contents on removal from storage at 42° to room temperature. There was an appreciable gain in sugar content during the 2 weeks following storage at higher temperatures. The Green Mountains kept at 60° for 29 weeks increased from 5.9 to 13.3 per cent in total sugars during the 2 weeks after storage.

It will be seen that the sum of corresponding values for starch and total sugars (both on the dry basis) in tables 1 and 2 gives total carbohydrates (minus cellulose and hemicellulose). These total values remain reasonably constant. Total carbohydrate values of potatoes after 2 weeks at room temperature following storage also agree well with those of potatoes taken directly from storage.

The Katahdins contained 74 per cent total carbohydrates on the dry basis at the time of entering storage. The percentages of total carbohydrate (averages for the entire storage period) were as follows: 34° F.—70 per cent at time of removal from storage bin and 69 per cent after 2 weeks of secondary storage; 36°—71 and 68 per cent; 38° F.—69 and 69 per cent; 42° F.—69 and 69 per cent; 50° F.—70 and 68 per cent; 60° F.—71 and 67 per cent. These data show little variation. There is, however, a drop from the original value, for which there is no ready explanation.

The Green Mountain potatoes contained 76 per cent total carbohydrates on the dry basis originally and, as the following average data show, there was little deviation at the various temperatures: At 34° F.—76 per cent at time of removal from storage and 74 per cent after 2 weeks at ordinary temperature following storage; at 36° F.—76 and 74 per cent; at 38° F.—77 and 75 per cent; at 42° F.—76 and 76 per cent: at 50° F.—77 and 76 per cent; at 60° F.—76 and 75 per cent.

The foregoing results show that under different conditions of storage an increase of sugars is accompanied by a corresponding decrease in starch, and *vice versa*. These data, however, do not take into consideration loss in weight during storage. The potatoes lost about 5 per cent of their original weight in 37 weeks' storage at 34° F., 5-½ to 6-½ per cent during the same period at 36° F., and about 7 per cent at 42° F. At 50° F., 6 to 6-½ per cent of the original weight had been lost at the end of 29 weeks; at 60°, the loss was 17 to 18 per cent during the same time.

It is of interest to know the loss in weight of starch and starch plus sugars occurring during storage. Table 4 shows loss of weight after storage at 34°, 36° and 42° F. for 13 and 37 weeks. Data for temperatures higher than 42° are omitted because they are of minor interest, owing to the fact that the temperature of Maine storage houses generally does not exceed this value.

TABLE 4.—*Loss in weight of starch and starch plus sugars during storage of Katahdin potatoes.*

Temperature Storage °F.	Loss of Starch During Storage for (Weeks)--		Loss of Starch Plus Sugars During Storage for (Weeks)--	
	13 Per cent a/	37 Per cent a/	13 Per cent a/	37 Per cent a/
34	24.3	29.1	15.8	19.4
36	29.4	31.6	12.9	17.9
42	11.3	15.6	10.4	15.6

a. Based on original content.

The conditions under which it was necessary to work in this study did not provide sufficient precision, especially in weighing, to permit determining differentially the amounts of sugar lost in respiration and consumed in synthesis to starch while the potatoes were held at room temperature after cold storage. Data taken at this Laboratory on other potatoes, however, show that sugars which disappear during reconditioning are converted at least partly into starch.

With the exception of the moisture content of potatoes which sprouted extensively, moisture content did not vary much from the original values. The moisture content of the potatoes held in storage for 29 weeks at 60° F. dropped only 1 to 1-½ per cent. Loss of weight, therefore, was generally distributed between water and solids in about the same proportion as in the original composition.

The Katahdin potatoes began to sprout in 7 weeks at 60° F. and soon afterward at 50° F.; incipient sprouting in this variety appeared after 13 weeks at 42° F. The Green Mountain potatoes stored at 50° and 60° F. started to sprout during the 13-week period. At 38° F., sprouting started in both varieties after 29 weeks but did not occur below this temperature even at 37 weeks. Sprouts were 1 to 2 feet long after 29 weeks' storage at 50° and 60° F., and the tubers were soft and shrunken. Katahdin potatoes in this condition were used to determine the composition of both the sprouts and the tubers. Although the sprouts constituted a minor fraction of the whole potato, table 5 shows that most of the reducing sugar was present in them. Total sugars were about equally divided between the two fractions. The sprouts fraction contained only a small amount of starch.

Although there are no generally accepted specifications for potato starch, the starch trade recognizes the following values as desirable: High degree of whiteness, low content of cold water-soluble material, low acidity, pH near 7, ash content about 0.35 per cent, low nitrogen content, and relatively high viscosity. Accordingly, these properties of starches produced in Maine factories in the fall of 1945 were compared with those of starches produced in the same factories in the spring of 1946. It was found that starch from the stored potatoes was essentially of the same

TABLE 5.—*Analysis of Katahdin tubers and sprouts after storage at 60° F. for 29 weeks.*

	Tubers		Sprouts	
	Based on Fraction	Based on Whole Potato	Based on Fraction	Based on Whole Potato
	Per cent	Per cent	Per cent	Per cent
Starch	15.4	13.1	3.1	0.5
Total sugars	0.37	0.31	2.58	0.39
Reducing sugars	0.1	0.1	2.55	0.38

Tuber fraction = 85 per cent by weight of whole sprouted potatoes. Moisture, 78.6 per cent.

(Sprouts fraction = 15 per cent by weight of whole sprouted potatoes. Moisture 90.7 per cent.)

quality as that from freshly harvested potatoes. Starches produced in 19 factories in the fall of 1945 and the spring of 1946, had the following average values: Whiteness (Measured with a G. E. automatic recording spectrophotometer; reflectance at 450 mu wave length compared to magnesium oxide at 100 was used), 82.5 and 82.2 respectively; cold water-soluble material, 0.25 and 0.23 per cent; acidity equivalent to 19.1 and 16.9 cubic centimeters of 0.1 normal sodium hydroxide per 100 grams starch; pH (measured with an electrometer; suspension of 1 gram starch in 5 grams water was used), 6.5 and 6.1; ash, 0.36 and 0.35 per cent; nitrogen, 0.01 and 0.02 per cent; viscosity of 2 per cent paste at 194° F., 572 and 615 centipoises.

DISCUSSION

From the point of view of the food consumer there is little loss in the food value (carbohydrate contents) of potatoes kept in cold storage. Growers who store their potatoes and later sell on a weight basis, however, will have to take into consideration the loss in weight. Shippers, dealers, and distributors who buy and sell potatoes must make allowance

for loss in weight, although their total percentage of carbohydrates remains practically unchanged. Potatoes kept in cold storage for 2 to 3 months contain only about 70 per cent of their original starch. If potatoes are to be processed for production of alcohol or other fermentation product in which conversion to sugar is the first step, or are to be hydrolyzed to crude glucose syrup, then stock taken directly from cold storage should be acceptable.

Sprouts are considered objectionable because they cause difficulties in washing the potatoes; starch manufacturers generally insist that they be removed prior to acceptance of the potatoes. Little starch is lost by their removal.

Summary and Conclusions

The effects of storage at 34° to 60° F. on the composition of potatoes was studied. The total carbohydrate content changed but little. Loss of carbohydrate material and of moisture occurred at about the same rate, so that the percentage of solids remained nearly at the original level. Potatoes removed from cold storage and kept for 2 weeks or more at ordinary temperatures increased in starch content. Potato sprouts contained little starch but a relatively large percentage of sugars. Commercial starch produced from stored potatoes in the spring of 1946 had essentially the same quality as that from freshly harvested potatoes in the fall of 1945.

Acknowledgment

The authors wish to acknowledge the splendid cooperation and help given by staff members of the Maine Agricultural Experiment Station during the course of this work. In particular we wish to thank Dr. Fred Griffee, Director and S. O. Hanson, Superintendent of Aroostook Farm, who placed the facilities of the Station at our disposal, and Michael Govern, who supervised the storage bins.

Determinations of whiteness of starch samples were made by Dr. Margaret L. Swain and nitrogen determinations were made under the direction of Dr. C. O. Willits, both of this Laboratory.

Literature Cited

1. Appleman, C. O. 1912. Changes in potatoes during storage. Md. Agr. Exp. Sta. Bull. 167, pp. 327-334.
2. Barham, H. N., Kramer, G., and Reed, G. N. 1943. Influence of various factors on the starch content of Kansas-grown potatoes and sweet potatoes. Jour. Agr. Res. 67: 395-406.
3. Barker, J. 1938. Changes in sugar content and respiration in potatoes stored at different temperatures. Great Brit. Dept. Sc. and Indus. Research. Food Inves. Board. Report for 1937, pp. 175-177.

4. Denny, F. E. and Thornton, N. C. 1942. The third year's results on storage of potato tubers in relation to sugar content and color of potato chips. Contrib. Boyce Thompson Inst. 12: 405-430.
5. Hopkins, E. F. 1924. Relation of low temperatures to respiration and carbohydrate changes in potato tubers. Bot. Gaz. 78 (11): 311-325.
6. Kimbrough, W. D. 1925. A study of respiration in potatoes with special reference to storage and transportation. Md. Agr. Exp. Sta. Bull. 276.
7. Müller-Thurgau H. 1882. Ueber Zuckeranhaufung in Pflanzentheilen in Folge Niederer Temperatur. Landwirtshaftliche Jahrbucher 11, pp. 751-828.
8. Official and tentative methods of analysis of the association of official agricultural chemists. 1945. 6th Ed., Washington. pp. 409-410.
9. Smith, Ora. 1933. Studies of potato storage. Cornell Univ. Agr. Exp. Sta. Bull. 553.
10. Steiner, E. T. and Guthrie, J. D. 1944. Determination of starch in sweet potato products and other plant materials. Ind. Eng. Chem., Anal. Ed., 16 pp., 736-739.
11. Stuart, W., Lombard, P. M., and Peacock, W. M. 1929. Comparative influence of different storage temperatures on weight losses and vitality of seed potatoes. U. S. Dept. Agr. Tech. Bull. 117, 18 pp.
12. Wright, R. C., Caldwell, J. S., Whiteman, T. M., and Culpepper, C. W. 1945. The effect of previous storage temperatures on the quality of dehydrated potatoes. Amer. Potato Jour. 22 (10): 311-323.
13. Wright, R. C., Peacock, W. M., Whiteman, T. M., and Whiteman, E. F. 1916. The cooking quality, palatability, and carbohydrate composition of potatoes as influenced by storage temperature. U. S. Dept. Agr. Tech. Bull. 507, 20 pp.
14. Wright, R. C. 1932. Some physiological studies of potatoes in storage. Jour. Agr. Res. 45: 543-555.